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ABSTRACT

In previous studies of educational systems, Markov chains have often been used in simulations in which history played no role because all events were described as independent of each other. Mono-level dynamics (i.e., the social context in which learning occurs is ignored) have also been applied to simulations. Educational theories, however, are usually multilevel in nature, since they describe pupil learning as a function of the characteristics of the group in which learning takes place. Moreover, teacher behavior is affected by organizational interventions. A three-level simulation model for educational effectiveness is presented. This mathematical model adequately describes the functioning of standard setting by teachers, which can be seen as the lever for raising performance levels. Experiments with the model show that it is almost impossible to achieve different, and possibly conflicting, policy goals simultaneously. The model is applied to two major educational policy programs in the Netherlands, the introduction of a Common Core Curriculum and a program addressing inequality of educational opportunities, the Educational Priority Programme. An appendix contains the source code for the model. (Contains 9 tables, 6 figures, and 28 references.) (Author/SLD)

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A hierarchical simulation model to study educational interventions

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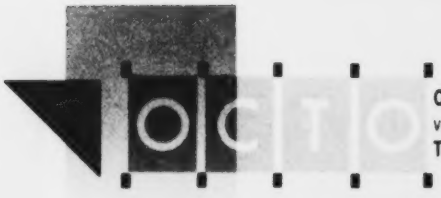

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A HIERARCHICAL SIMULATION MODEL TO STUDY EDUCTIONAL INTERVENTIONS

R.J. Bosker

H. Guldemond

november 1994

UNIVERSITY of TWENTE

Centre for Applied Research in Education
Enschede

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Abstract

In earlier simulation studies of educational systems usually Markov chains are used (i.e. simulation in which history plays no role since all events are described independent of each other) or mono-level system dynamics (i.e. a simulation of how learning takes place ignoring the social context in which it occurs). Educational theories, however, are usually multilevel in their nature, since they describe pupil learning amongst others as a function of characteristics of the group in which this learning takes place. Moreover, teacher behaviour is affected by organizational interventions. A three-level simulation model for educational effectiveness (3LS) will be presented. The model adequately describes the functioning of standard setting by teachers, which can be seen as the lever for raising performance levels. Experiments with the model show that it is almost impossible to achieve different (possibly conflicting?) policy goals simultaneously.

Foreword

At the end of the eighties educational science made a step forward by a theoretical and a statistical innovation. The theoretical innovation was the educational effectiveness programme. As Coleman (1989, 2) stated it:

> *"Without this shift, the hard questions would have remained: Which school inputs make for differences in outputs? What difference does the school a child goes to make in the child's achievement? How much do schools overcome the inequalities with which children come to school? One might wonder why educational researchers had not asked these questions long ago, why they had not always focused on outputs of schools in assessing their quality. (...) Researchers characteristically do not study the effectiveness of teachers by measuring what teachers do and comparing their activities to what children learn. Instead, they carefully study what teachers do but seldom examine what their students learn. (...) Beginning with the publication of the Equality of Educational Opportunity report, the first hurdle was cleared and schools' effectiveness could be measured by the performance of their students."*

The statistical innovation was the introduction of the multi-level statistical model that made it possible to test educational hypotheses on, e.g., teacher effects on pupil achievement, while more adequately modeling the hierarchical nature (pupils nested within teachers) of the data. Uptil this point the conclusion could have been no other than (Cronbach, 1976, 3):

> *"The majority of studies of educational effects - whether classroom experiments, or evaluations of programs, or surveys - have collected and analysed data in ways that conceal more than they reveal. The established methods have generated false conclusions in many studies".*

The theoretical and statistical improvement makes it possible and worthwhile to study educational phenomena from a multi-level perspective. Thinking through the

implications of the hierarchical and sequential nature of educational systems, however, now forced by the theories that try to link organizational and instructional characteristics with pupil behaviour, and trying to formulate these ideas in a multi-level precise fashion shows the shortcomings of mental models. Therefore in this report an attempt is made to formulate such a model in mathematical terms, and then using the computer to run simulations and study the behaviour of this model. This report then tries to explore two things at the same time: the possibilities of constructing a simulation model of educational effects, and the use of such a model in forecasting the effects of new educational policies.

The model is a completely redesigned version of the simulation programme outlined in Bosker et al. (1988). The programme written in Pascal is included in the appendix to this report. For those who study this report to find out the possible working of the new Common Core Curriculum ("de Basisvorming") or the Educational Priority Programme ("het OnderwijsVoorrangsBeleid") a cautionary note is in place: the forecasted effects are only true in so far as the simulation model is valid. For those who study the simulation model the cautionary note is: the effects forecasted by the model are only true in so far as our translation of the policies into scenarios is valid.

One thing is for sure: the conceptualization and mathematical formulation of the model forces us to explicit assumptions and theoretical propositions which helps in finding gaps in the theory and gaps in the empirical justification of this theory. As far as we are concerned: this is only the beginning.

Henk Guldemond was responsible for programming the simulation model (see the appendix), while the remainder of this report was written by Roel Bosker.

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Chapter 1: Introduction

Understanding social systems is hindered by their overwhelming complexity. Understanding possible effects of changes in these systems is even more difficult. It is for this reason that comparative education is a useful discipline within the educational sciences, although using insights in the structure and working of a foreign educational system often is impeded by the specific societal and cultural conditions under which such a system functions. Understanding the impact of innovations that have no parallel in other countries is even more complicated. The feasibility of ex ante evaluation of two major policies that are in effect at the same time depends on the rationality of these policies. If there exist clear goals, and complete information on means and ends is available evaluation can be restricted to a logical analysis. But of course, this is hardly ever the case. The situation even deteriorates when there are more goals to be achieved at the same time. Mental models of causes and effects certainly fall short here. This exactly is the situation in the Netherlands, where two major policy programmes are aimed at improving the functioning of secondary education. The introduction of a Common Core Curriculum aims at improving excellence and efficiency, whereas the Educational Priority Programme tries to reduce inequality of educational opportunities.
It is for these reasons that in this report an attempt is made to evaluate these innovations beforehand by using a simulation model, based on a combination of two interdisciplinary theories (general systems theory and rational choice theory) and two educational theories (the Carroll model of instructional effectiveness and the school effectiveness model).
The attempt to be made in this report is a precise formulation of these educational theories, then restating the model in mathematical terms, validating it, and then using it for prospective purposes deriving specific hypotheses on effects of the two beforementioned policy programmes in the end.

In the sequel of this report a multilevel simulation model of education will be introduced, as an aid to forecast the consequences of policy interventions. Therefor the following steps will be made:

1. problem definition
2. system conceptualization
3. model representation
4. model evaluation
5. evaluating alternative scenarios for policy intervention.

The report starts with an outline of the Dutch educational system, the Common Core Curriculum, and the Educational Priority Programme (chapter 2). Then simulation as a tool of forecasting is discussed in chapter 3, illustrating the technique with applications in the field of educational science. System conceptualization departing from the rational choice approach to the explanation of compositional effects in education as proposed by De Vos (1986, 1989) is dealt with in chapter 4. Chapter 5 focuses on the mathematical formulation of the model, and chapter 6 contains some empirical research aimed at validating the model. In chapter 7 then, the Common Core Curriculum and the Educational Priority Programme are formulated as three alternative scenarios, that are then evaluated using the simulation model. Finally, chapter 8 summarizes the main results, offers some specific hypotheses to be tested in empirical research, and highlights the main directions for a more refined simulation model.

Chapter 2: Defining the problem

The Dutch system for secondary education is categorical: at the age of thirteen pupils have to decide what type of school is most suited to the individual pupils' aims and cognitive capacities. Generally speaking they have four options (ranked in increasing difficulties):

1) JVE (LBO): junior vocational education (duration: four years),
2) IGSE (MAVO): intermediate general secondary education (duration: four years),
3) HGSE (HAVO): higher general secondary education (duration: five years),
4) PUE (VWO): pre-university education (duration: six years).

Switches between the schooltypes are possible before or after acquiring a certificate.

This secondary school system has at least five distinct disadvantages. The first and main problem is that choices between the four main streams (JVE, IGSE, HGSE, and PUE) are actually made when the pupil is twelve years old, despite the one-year orientation period in secondary education, intended for selection and determination purposes. The reason is quite clear: most schools for secondary education are categorical; choosing to follow your orientation period at a HGSE school implies with almost 100% certainty a HGSE school career. This means that the pattern of the school career for about four years is determined by a choice made at the end of primary education. The selection of pupils when they are aged 12 is far too early. As a consequence, pupil background variables bear a strong relationship to choice of school career. This relationship is much stronger than might be expected judging by differences in intellectual abilities (cf. Tesser, 1984).

The second problem is, that the degree of flexibility in the system is below expectation. As already mentioned, switches between the main streams are possible. A downward switch, however, is most likely: it happens to one out of ten children and is five times more likely than an upward switch after completing the first stream chosen (Sociaal Cultureel Planbureau, 1982). Although comprehensive schools were introduced, offering two or three categorical streams as an option to increase the flexibility of the system, their success has been below expectation for the more able pupils (cf. Kreft, 1987): pupils in categorical PUE schools seem to be better off than equally able pupils in comprehensive schools. Furthermore, the

curriculum track chosen one (JVE and IGSE) or two years (HGSE and PUE) before completing secondary education, strongly determines the possible choices for further education in colleges, senior vocational education and so on. As a result of not choosing mathematics and science subjects at school, girls have a more limited range of possibilities than boys. The third problem is that curricular contents are very different in the vocational and general stream: gaining a broad cultural and scientific knowledge is the privilege of children in the general streams, whereas the vocational schools concentrate on learning practical skills for the job market. The fourth problem is, that, because of the fourfold division in Dutch secondary schools, pupils with different backgrounds are usually completely separated from each other. Social integration is thus limited after a secondary school is chosen. The fifth and last problem is, that many pupils never gain a school-leaving or final exam certificate. Ten percent of all pupils drop out of the system before completing school.

After many plans were unfolded to solve these problems, eventually public support was given to a plan not aimed at restructuring the old system into a horizontal one, but introducing common achievement norms. The essential idea of this plan is that all secondary schools have the same basic curriculum in the first three comprehensive years of secondary education, with 14 subject areas and a common achievement level. The main differentiation principle should be such as to allow some pupils to reach the standards within a shorter period, and allowing other pupils to reach the standards in four years when necessary. In this way, the educational level of all pupils should increase. Besides this, the correlation between background variables and school career should decline. This is also the objective of the Educational Priority Programme, that mainly focuses on improving opportunities for disadvantaged pupils in primary schools. Resources, however, are also made available to regions where there is a high concentration of lower class and/or ethnic minority pupils. In a collaborative effort primary schools, social agences, and secondary schools then will try to improve the educational opportunities of these pupils. In 1993 the first schools will begin to implement the characteristics of the Common Core Curriculum. The study described in the sequel of this report explores the possible outcomes of this innovation. Our main objective is to study whether it is possible to achieve three goals at the same time:

increasing the overall achievement level, improving the efficiency of the system, and decreasing inequality of opportunities in education.

Chapter 3: About simulation

Education as a social system is very complex. Geurts (1983) describes this complexity in four domains:

1. multivariate complexity: social phenomena are caused by many causal forces at the same time
2. multilevel complexity: individuals, groups, and other social entities constitute larger social connections and they are in their turn influenced by these
3. multirelational complexity : relations between parts of a social system can take on various forms, like unidirectional causation, reciprocal causation, and feedback-loops
4. timecomplexity: social systems develop over time and do not have same patterns of behaviour at various points in time

Although it is possible to construct mental models of social systems, these models are inadequate to understand the complex dynamic properties of these systems. For this reason the construction of formal models may be of help, since these are clear and verifiable and easily to manipulate.

By presenting three examples of simulation as a tool to study educational phenomena, the basic principles, advantages and shortcomings of this technique can be demonstrated.

3.1 Boudon's dynamic IEO model

Anderson's paradox is the point of departure for Boudon to study inequality in education and society. This paradox is the empirical observation that the correlation between a son's social status and his educational level relative to the father's is low. This fact seemed to contradict the idea of industrialized societies becoming more and more meritocratic. Although this problem deals with inequality of social opportunity Boudon's work is of relevance for us here since he formulated a partial model to explain inequality of educational opportunity (IEO for short). Boudon (1974, 67-68) strived for a dynamic model in the sense that he wanted to simulate the school careers of a school cohort of pupils, i.e. the careers of a set of

youngsters who attend the last grade of elementary school at some time. Next to this Boudon aimed at a system-dynamic model, i.e. a model that would allow to predict the differences between different school cohorts.

We will confine ourselves to present the main features of Boudon's IEO model, by simply presenting only the 6 most important of his eight auxiliary axioms:

1. There are three social classes called C1 (high), C2 (middle), and C3 (low);
2. At any time 10,000 C1 youngsters, 30,000 C2 youngsters, and 60,000 C3 youngsters will finish elementary education;
3. There are three achievement levels, R1 (high), R2 (middle), and R3 (low);
4. Social class is related to achievement according to the following table:

Table 3.1: The relation between social class and achievement

	R1	R2	R3
C1	60%	30%	10%
C2	50%	30%	20%
C3	30%	40%	30%

5. The educational system can be simplified as a higher curriculum versus dropping out. At eight points in his career a pupil has to choose between staying in the higher curriculum or not. By definition this implies that there are 9 distinct educational levels. The chances to survive for a given social class and achievement level are:

Table 3.2: Survival probabilities as a function of social class and achievement

	R1	R2	R3
C1	.85	.75	.65
C2	.70	.60	.40
C3	.60	.40	.20

6. Survival probabilities (p) increase over time (t) according to:

$$p_{t+1} = p_t + (1-p_t).10$$

The last axiom is presented to construct a model in which new generations of youngsters in a society tend to choose the higher curriculum more often then preceding generations. The specific form of the formula imposes a ceiling effect on this phenomenon. The formalization introduced by Boudon is very simple, but nevertheless some simple empirical facts can be reproduced by this model. To start with the proportion of upper class pupils surviving at a branching point relative to the proportion of lower class pupils increases with the level of education (e.g. this disparity index is higher at the 6th branching point than at the 5th). The well known disparity index for the college level for some countries (18) can be readily reproduced by the model, the index meaning that a higher class pupil has a chance that is 18 times higher than that of a lower class pupil to survive in the higher curriculum untill college.

By modifying auxiliary axiom 4, stating that social class has no relation to achievement (i.e. for all social classes the distribution over achievement levels is 60%, 30% and 10%), Boudon found that the disparity rate only reduced to 10. Stated otherwise: class-specific selection and choice-processes are more important than class-specific achievement differences in explaining IEO.

More important, however, are the dynamic properties of the model, i.e. the changes in IEO when comparing several school cohorts and allowing for a (small) increase in the probabilities to survive at each branching point. Although at each

branching point lower class pupils will have a greater increase in these probabilities than higher class pupils (as a consequence of the ceiling effect imposed on the model by auxiliary axiom 6), the amount of IEO will hardly decrease. Moreover, the amount of decrease in IEO will slow down over time. As compared to the described situations, the disparity index for the college level will have been improved from 18 to 10 after four cycles, but it still shows an enormous amount of IEO. Given Boudon's parametrization the number of pupils attending college will have been doubled (from 6% to 12% of the pupil population) after four cycles. Or to combine these two observations: the more developed the educational system, the weaker is IEO. Boudon's general conclusion, however, is that as long as stratification exists either in society or in education or in both IEO will be the consequence. Survival probabilities for lower class pupils can be altered by altering expected utilities of choosing the higher curriculum, which is a complex task. In a critique on the distinction between primary effects (via achievement) and the secondary effects (via the survival probabilities) of social stratification, Bosker (1990, 13) contends that the relation between social class and achievement may change (become stronger) as a school cohort of pupils advances in its careers. Then the secondary effects might be purely on artefact of the model as it is constructed by the axioms. Nevertheless, Boudon's approach showed that it was possible to study a complex social phenomenon like IEO more detailed by simulation techniques.

3.2 The structure of student-teacher interactions

Combining research on self-esteem, standards, expectations, student ability, and instructions Levin & Roberts (1976) constructed with the help of DYNAMO (developed by Forrester to forecast industrial development; see Roberts et al., 1983) a model of student-teacher interaction. Although the model seems quite complex simplicity can be found in the metrics used: time and performance units. Figure 3.1 shows the model in a systems graph.

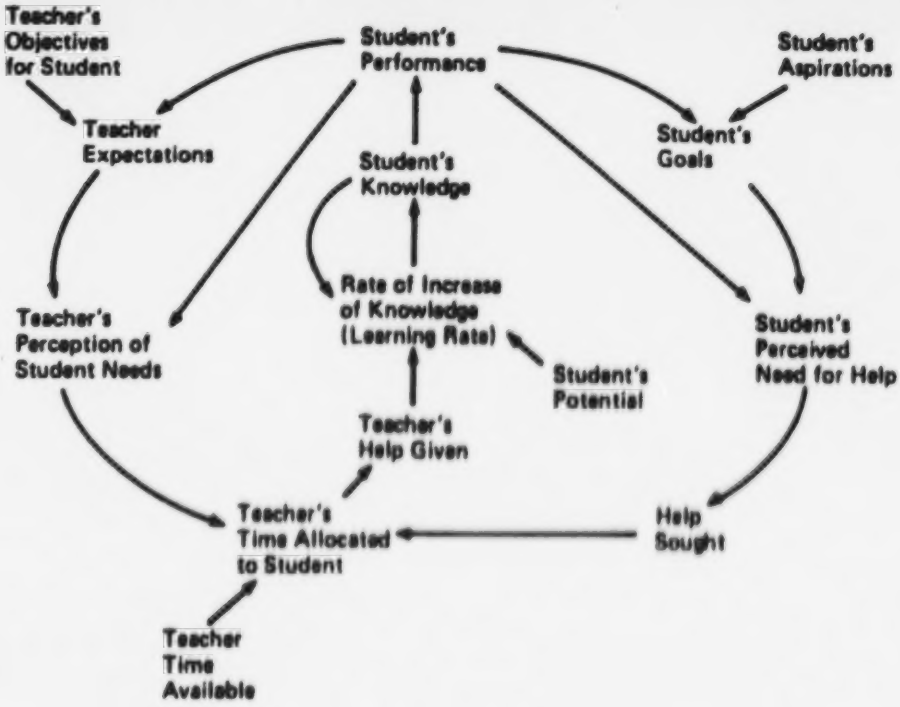

Figure 3.1: Systems diagram of student-teacher interaction as it affects classroom performance

The model speaks for itself, so to speak. The authors summarize the model as follows (Levin & Roberts, 1976, 99):

> *"In review, during the course of a school year, a child adjusts his goals so they are in line with his performance. The gap between how well a child is performing and how he would like to perform determines the amount of teacher help the child thinks he needs. This in turn influences the amount of help the student seeks, which affects the amount of time and help the teacher gives the student. This help, combined with the student's innate potential and current store of knowledge, influences his rate of learning. Learning rate increases as the student's knowledge base increases. This knowledge accumulation will then determine the student's performance. (...)*

As they have been described, each of the two main modeled feedback loops can lead to cyclic fluctuations in student performance, accompanied by fluctuations also in student goals and teacher objectives, in help-seeking and help-giving, and in student rate of learning. The student and teacher are clearly shown as affecting each other, with student performance being the joint product.

Each modeled loop also reflects the processes whereby goals or objectives shift to accommodate short-term performance. Through these changes over time either the student or the teacher or both can turn off the help-seeking/help-giving interchange that so critically influences the dynamics of performance."

Notice that the model contains a negative feedback-loop structure: it is a goal-seeking system. The lower the performance the level, the more time is allocated, the better the performance, the less time is allocated, etc. Another important feature, not shown by the graph, is the delay in response that Levin & Roberts build into the model: it may take some time, for example before a teacher perceives a gain in performance level. Conceptually the model focuses on what might be called the "learning gap": the discrepancy between ability and achievement and/or the discrepancy between standards (goals) and achievement. Since we will elaborate on this idea in chapter 4 one table presented by the authors on the outcomes is of particular interest:

Table 3.3: Performance under different specifications of the model

		student performance	
teacher expectations	student goals	time 10 h/w	time 20 h/w
75	80	75.5	76.2
75	95	76.0	77.0
95	80	76.8	78.0
95	95	82.0	84.8

Time (measured in hours per week) is not so much important as is teacher expectations and student goals, (given the parametrization chosen by the authors). A problem with this model, however, is that the context of learning (classrooms and schools) is totally ignored. This condition, as Barr & Dreeben have demonstrated (1983), is vital in understanding school learning.

3.3 A system perspective on effective schools

Clauset & Gaynor (1982) tried to construct a model to conceptualize the basic idea "that schools are systems that produce *multiplier effects* (that is, they reinforce initial patterns of achievement)" (Clauset & Gaynor, 1982, 55). As with the Levin & Roberts' model the point of departure is the interaction between instruction and learning conceived as a negative feedback loop (oscillating goal-seeking behaviour). The systems graph underlying the model (that once again was build using DYNAMO) is presented in figure 3.2.

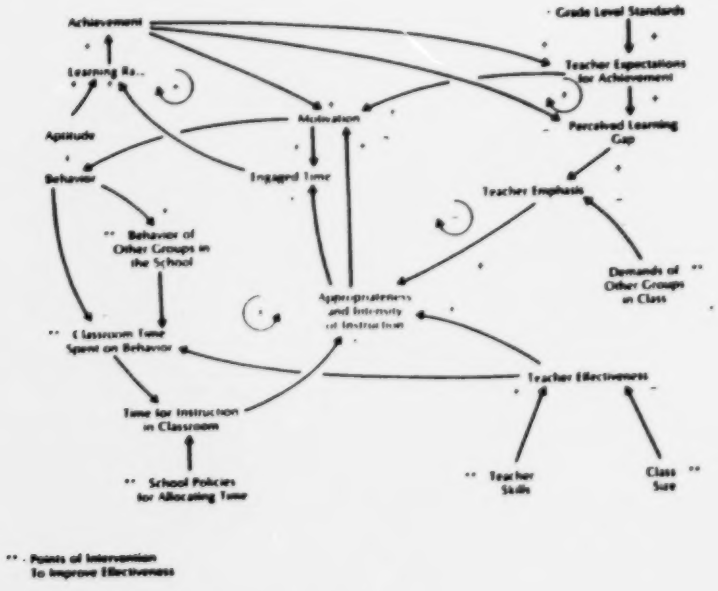

Figure 3.2: A dynamic theory of schooling.

The authors explain the background of this model as follows (Clauset & Gaynor, 1982, 55):

> *"In an effective school, teachers and the principal maintain high expectations of the achievement of all but the clearly exceptional student. They assume that, regardless of family, background or social class characteristics, all children can learn at a normal rate and can achieve standard (or better) levels of performance during their schooling. In an ineffective school, expectations for achievement are neither high nor fixed. Children who enter school with a lower level of reading readiness or who are from lower socioeconomic classes are categorized as low achievers (Rist, 1973). It is assumed that there is little the school can do to offset the impact of preschool, family, and environmental conditions.*
>
> *This feedback relationship involving achievement, expectations, and instruction is the backbone of our dynamic theory of schooling."*

The conclusions drawn after running the model lead to the following conclusions:

1. Interventions should focus on raising teacher expectations;
2. Maximize time for instruction.

This last conclusion could also be drawn from the Levin & Roberts' model, although they argue that standards are far more important. As with Levin & Roberts the condition of schooling (Bidwell & Kasarda, 1980) plays no role. Although class- and schoollevel variables are included in the model, actually it is run as a mono-level, i.e. a pupil-level, model, assuming that the behaviour of other pupils in the classroom has no effect on the process.

Chapter 4: System conceptualization

In order to forecast the consequences of the innovation outlined in chapter 2, first of all a conceptualization of secondary schooling has to be accomplished. This is done by applying the elements of the well known Carroll model and using a model developed by De Vos (1989), based on the interdisciplinary theory of rational choice. It integrates pupil learning, instruction and school organization models. By means of this model, the progress pupils make in schools as a result of their prior cognitive abilities, the heterogeneity of the instructed group, the standards that teachers set for pupils and the time available for individual help can be simulated. The simulation will be hierarchically, longitudinally organized reflecting key features of educational organizations: the nesting of pupils in classes, the nesting of classes in schools, the dependency of adjacent grades by those pupils who repeat a grade, the dependency of adjacent curricular tracks by those pupils who drop out of one track to proceed in the next lower one.

The most dynamic process in education is pupil learning. The mono-level background of the multilevel theory is the well-known Carroll model of instruction. A simplified form is depicted in figure 4.1.

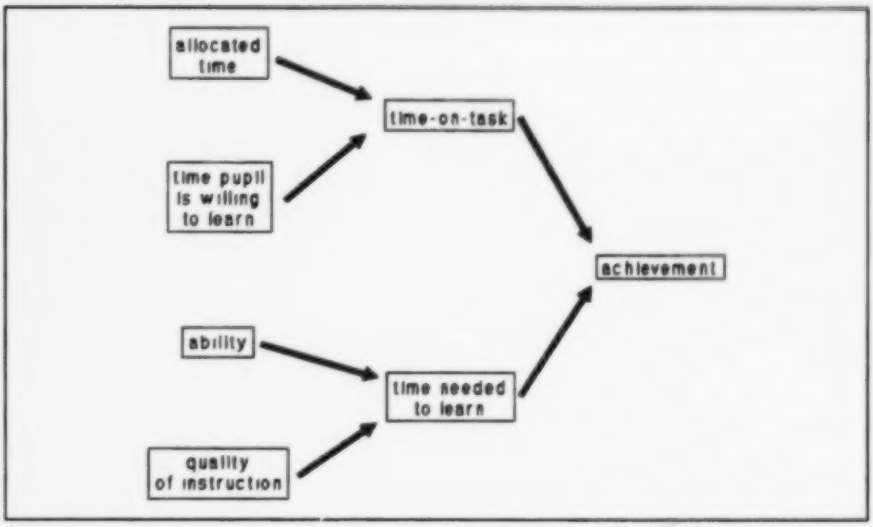

Figure 4.1: The key-variables of the Carroll model (Carroll, 1989).

This scheme is used in mastery learning. It does not have, however, the multilevel character of learning and instruction. Standards that teachers hold for pupils as well as the allocated learning time are constrained not only by ***pupil*** but also by ***group*** characteristics. Ability grouping research, for instance, indicates that pupils learn less in a low achieving group than in a high achieving group and, moreover, that initial low achieving pupils differ more in learning from high achieving pupils in homogeneous than in heterogeous grouping (Gamoran, 1986; Dar & Resh, 1986; Guldemond et al., 1989; De Vos, 1989).

Research on ability grouping (Dar & Resh, 1986) suggests that pupil ability within a class affects the standards as well as the instructional quantity. An educational effects model should therefore incorporate non-recursion. Learning and instruction can then be depicted as in figure 4.2 (i.e. two-way causation, as in feedback relationships).

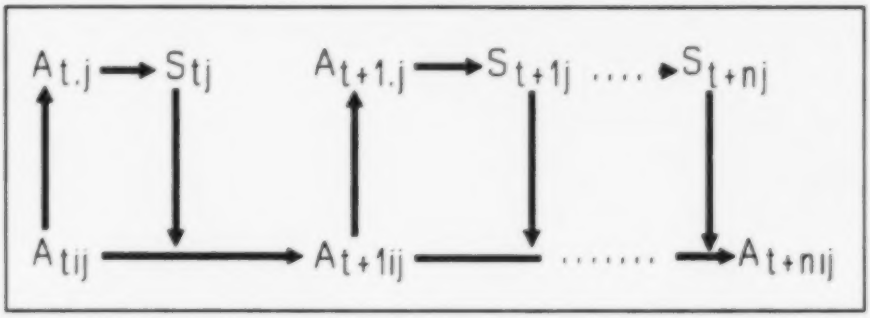

Figure 4.2: The non-recursive relation between teacher's standards and pupil achievement.

Average achievement of class j at timepoint t ($A_{t.j}$) thus affects the standard set by the teacher for the next period of teaching (S_{tj}). Prior achievement of pupil i in class j at timepoint t (A_{tij}), the standard, and the interaction between the two lead to an increase in achievement (A_{t+1ij}), etc. This mechanism may explain the sizeable effects of group level aggregates of pupil variables, next to the effects of the pupil variables themselves, on pupil achievement, as they are generally found in school effects research. Hauser (1974) has contended that these effects can be merely demonstrated if the pupil level model is underspecified (i.e. does not contain all individual level variables that could account for achievement differences). Kreft (1987) has argued that the reverse may also be true: individual variables may be shown to have an effect since the group level model is underspecificied.
The principle that can explain these factors is the gap between the actual performance of the pupil and the standard. The larger the gap the less utility a pupil is expecting of learning. This idea is simulated with success in the mono-level studies presented in chapter 3. In the sequel we will present a multi-level approach to model these phenomena.

The conceptualization is derived from De Vos' model of composition effects in education (De Vos, 1989). As with Boudon, De Vos starts with the rational choice approach, stating that pupils strive for social approval from the teacher, such as support and grades. Teachers also strive for social approval from parents and colleagues. As with the DYNAMO-models of Levin & Roberts and Clauset &

Gaynor, standards play a key role. Conceptually the empirical basis for giving this concept a central place in the model can be found in school effectiveness research, where time and again (c.f. Scheerens, 1992) "press to achieve" turns out to be one of the central elements in the effectiveness enhancing school organization. The implication of standards are simple: a high standard means giving lower grades for the same achievement level, setting a faster pace, and disapproving longer with pupils' performance levels. Now combining teacher and pupil behaviour De Vos summarizes the central proportions as follows (De Vos, 1989, 228):

"1. students' marginal utility for achievement is dependent on teachers' evaluations and is highest at teachers' standards;
2. teachers' standards are dependent on the average achievement level of the class or ability group;
3. students in the same class or group are confronted with the same standards and therefore have the same marginal utility function of achievement, and;
4. the marginal cost function of students depends on their individual ability and therefore varies between students."

The connections between pupil, class and teacher run as follows. The higher the average achievement level, the higher the standard. Giving a certain performance level pupils have cost utility considerations, that lead to a net utility (approval versus efforts) corrected for the subjective probability of goal attainment. In its turn this subjective probability is higher as the pupil has more succesfull fellow pupils. This last idea is borrowed from social comparison theory.
With his model De Vos is able to explain the sizeable effects of average group characteristics. Although we will not dwell on it in the formulatation of the model, a nice feature of De Vos' model is that it forecasts differential composition effects that are actually described in the literature. This forecast is based on figure 4.3.

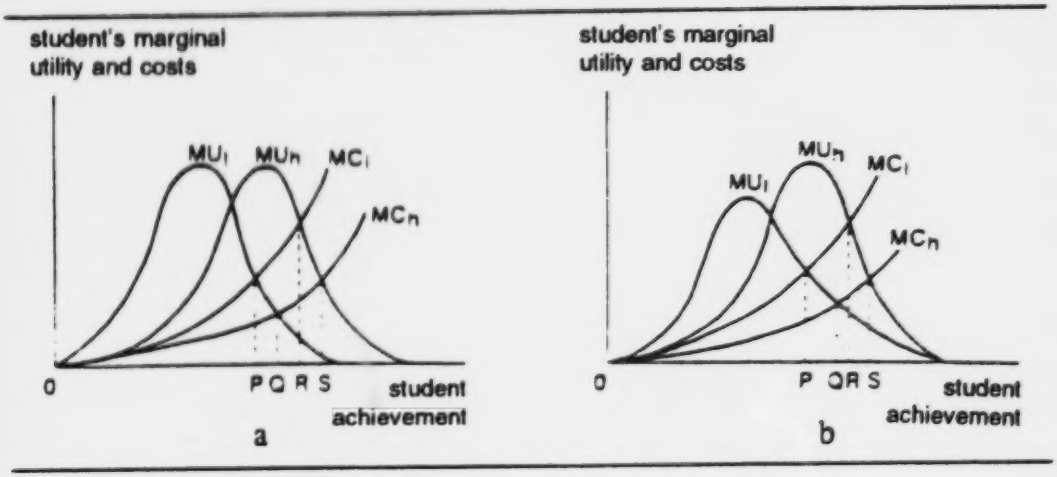

Figure 4.3: differential composition effects

De Vos explains the differential effects by referring to the graph (De Vos, 1989, 229 (erratum version)):

"a. *Marginal cost functions of low-ability (MC_l) and high-ability (MC_h) students in a low average achievement class (marginal utility function MU_l, i.e. a low standard). Low-ability students achieve at level P in a low average achievement class. High-ability students achieve at level Q in a low average achievement class and at level S in a high average achievement class;*

b. *Same as a., but with a teacher in the low average achievement class who gives the (relatively) high achieving students he has, more approval at the cost of students who achieve at and around his standard. The effect of this teacher strategy is that MU_l has a long right tail and a lower maximum. Now the difference between the achievement levels of high- and low-ability students in a high average achievement class (OS - OR) is smaller than in a low average achievement class (OQ - OP)."*

De Vos contends that higher standards lead to more pace. In this respect it seems worthwhile to introduce allocated time as a variable to the model, to capture the second main aspect of the Caroll model. Except for empirical research (c.f. Walberg & Friser, 1989), that demonstrated relevant and malleable effects of this instructional variable, we also are in the position to model differential teacher effects without modifying the uniform standard held for all pupils of a class.

The complexity that is not yet in the model can be described as the Frisian paradox, the concept stemming from a Dutch joke on Frisians (people residing in a Dutch province striving for independence) and Belgiums (as known the neighbours): what happens when a Frisian moves to Belgium? Mean IQ in the Netherlands as well as in Belgium will raise! This phenomenon will occur if we allow for adjacent grades, adjacent curricular tracks, and adjacent school cohorts. When demotion from the standard reaches a maximum a pupil will repeat a grade, drop out or switch to a lower curricular track. Now this change does not only affect the class of pupils he leaves (and by this also the standard the teacher will set) but also the class of pupils he then enters. Exactly this complexity calls for a simulation.

Chapter 5: Model representation

The general conceptualization outlined in chapter 4 will be given a more operational, mathematical form in this chapter. First of all we have to choose system boundaries. We assume to study a categorical education system with four curricular tracks with varying degrees of difficulty. Furthermore this system is restricted to four grades. These restrictions are a simplification of the Dutch education system described in chapter 2. We will not study comprehensive schools, since once the pupil is assigned to a curricular track it can be known how achievement levels are distributed over the tracks where pupils started their career directly after leaving primary school. The limitation to four grades has two reasons. First of all the innovation that we want to study, concerns this part of secondary schooling. Moreover, the interconnections between the four tracks become very loose after the fourth grade with other tracks (mainly in senior vocational education) being a realistic alternative for pupils opting for change. Another restriction imposed on the model is, that only one class per grade per cohort per school will be studied. Since we study a categorical system it is no loss of generality to assume that classes within a school (for a certain grade grade and cohort) would have equal distributions on the variables of interest. The last assumption is that achievement is onedimensional, which ofcourse ignores the many subjects taught in secondary education. Achievement in the model might be thought of as averaging over the subjects of the curriculum.

Learning gain is defined in the model as a function of attributes of the pupil (IQ, socio-economic status and a performance rating made by the teachers of the primary school), the standard a teacher sets for his class, available instruction time and chance (random fluctuation, or stated otherwise: effects of variables that are not in the model). First of all the standard is set as a function of the mean achievement level of the class. The reason for this is, that standards set too high may work demotivating, and they only function for the pupil as a normative reference point if they are near the actual performance level. According to comparative reference theory (Richer, 1976) this standard can be seen only as a positively motivating striving point if the pupil sees other classmates functioning near the standard. In heterogeneous classes this will be more likely than in

homogeneous classes. This is the notion associated with De Vos' model concerning the subjective probability of goal attainment. Heterogeneity has been demonstrated to have such a positive efect in secondary education (De Vries, 1992). Formalized:

(1) $STANDARD_{jk}$: = 0.5 $SD(ACHIEV)_{jk}$ + $MEAN(ACHIEV)_{jk}$

The standard a teacher sets for his class is the mean achievement level plus half of a standard deviation of the achievement in his class.

Next to the standard the degree of over- or underachievement is a determinant of learning gain The degree of overachievement is measured by comparing a pupil's actual performance level with his predicted performance level, where the prediction is based on socio-economic status, IQ, sex and the teacher rating at the end of primary education.
The standard procedure to accomplish this is by regressing achievement on the background attributes:

(2) $ACHIEV_{ijk} = \beta_{0jk} + \beta_1 SES_{ijk} + \beta_2 IQ_{ijk} + \beta_3 RATING_{ijk} + \beta_4 SEX_{ijk} + e_{ijk}$

(3) e_{ijk} = observed($ACHIEV_{ijk}$) - predicted($ACHIEH_{ijk}$)

The residual for pupil i in class j in school k then simply is our measure of overachievement. This variable will further be referred to as $RESIDUAL_{ijk}$.

The next step concerns the degree to which a pupil will make an effort to accomplish learning gain. Following the rational choice models of Boudon (1974) and De Vos (1989) this effort is dependent on a cost-benefit analysis made by the pupil. The effect of socio-economic status is explained by these authors by different equilibrium points for the different social strata.

The equilibrium points are defined as

(4a) $EQUIL_{ijk}$:= $MEAN(ACHIEV)_{jk}$ for low SES pupils

(4b) $EQUIL_{ijk}$: = $0.5(STANDARD_{jk} - MEAN(ACHIEV)_{jk})$ for middle class pupils

(4c) $EQUIL_{ijk}$: = $STANDARD_{jk}$ for high SES pupils

Taking into account the definition of the standard in (1) low SES pupils reach their equilibrium point half a standard deviation below the standard, middle class pupils a quarter below the standard, and high SES pupils at the standard set by the teacher.

From (3) and (4a) through (4c) we can derive two possible situations: pupils who do not have (yet) reached their equilibrium point (I: $RESIDUAL_{ijk} < EQUIL_{ijk}$) and pupils who did accomplish this already (II: $RESIDUAL_{ijk} \geq EQUIL_{ijk}$).

Situation I: without loss of generality it can be assumed that the equilibrium point for a certain SES-group is 0. Furthermore the residuals can be rescaled to z-scores.

(5) $ACHIEV^{t}_{ijk} = ACHIEV^{t-1}_{ijk} + (1 - \int_{ACHIEV}^{EQUIL} \{(1/\sqrt{2\pi}) e^{-(X^{*}X)/2}\})^{*}RANDOM(0..SD(ACHIEV)_{jk})$

The first part of (5) that needs explanation is the integration part. This is the surface under the standard normal distribution between the actual achievement level of a pupil and his equilibrium point. Since 1 minus this surface is used, the difference for two pupils with small differences in actual performance levels but near their equilibrium point is smaller than for two pupils with the same small differences in school performance levels but further away from their equilibrium point. By taking this into account we have succeeded in formal modelling the fact that pupils near their equilibrium point have a greater chance of making progress, whereas being further away may lead to demotivation.

The second part of (5) that needs explanation is the RANDOM-part. The progress a pupil makes is to a certain degree unpredictable. RANDOM(0..SD(ACHIEV)$_{jk}$) should be read as: pick a random number between 0 and SD(ACHIEV)$_{jk}$. Since heterogeneity is part of this function pupils in heterogeneous groups have a greater chance of making more progress. This reflects the idea of comparative reference processes: pupils in heterogeneous groups see classmates functioning near their equilibrium point as positively motivating examples: in other words, the subjective expectation of goal attainment increases as the distance to the equilibrium point decreases as well as when classmates function near the equilibrium point.

Situation II:

(6) $ACHIEV^{t}_{ijk} = ACHIEV^{t-1}_{ijk} + RANDOM(0..SD(ACHIEV)_{jk}) - 0.5\ SD(ACHIEV)_{jk}$

For pupils that have already reached their equilibrium points and that are not achieving below expectation the mean progress is exactly zero, since the mean of RANDOM(0..SD(ACHIEV)$_{jk}$) is equal to 0.5SD(ACHIEV)$_{jk}$.

Instructional quantity is the next factor to be modelled. An increase of it leads to more learning gain, but its marginal effects decreases rapidly (the difference between using 10% or 20% of the available time for instruction has greater effects on learning gain than, say, between 80% or 90%).

For a class j the time actually used for instruction is defined as the percentage of the time available:

(7) T_j := RANDOM(10..100)

By introducing a log-function the marginal effects of instructional quantity on learning gain can be modelled. Again, like before, the situation is different for pupils below and above their equilibrium points:

Situation I:

(8) $ACHIEV^{t}_{ijk} = ACHIEV^{t-1}_{ijk} +$

$+ (\log(T_j)/\log(55))^{*}(1-\int_{ACHIEV}^{EQUIL}\{(1/\sqrt{2\pi})e^{(X^{*}X)/2}\})^{*}RANDOM(0..SD(ACHIEV)_{jk})$

Situation II:

(9) $ACHIEV^{t}_{ijk} = ACHIEV^{t-1}_{ijk} +$

$+ (\log(T_j)/\log(55))^{*}(RANDOM(0..SD(ACHIEV)_{jk}) - 0.5\ SD(ACHIEV)_{jk})$

Mean learning gain in the population is not affected by introducing instructional quantity into the model, but differences between schools in learning gain are now introduced.

Selection effects (i.e. that some schools get better pupils than other schools) are simply introduced as follows:

(10) $newACHIEV_{ijk} = oldACHIEV_{ijk} + \beta_{jk}$

where we have pupil i of generation j in school k. Furthermore:

(11) $\beta_{jk} = u_{jk} + u_{k}$

in which $u_{jk} \sim (0,0.05)$ and $u_{k} \sim (0,0.1)$ with $var(ACHIEV_{ijk}) = 1$.

This way between schools differences in initial achievement levels make up 10 percent of the total variation in initial achievement, and the generation effects within schools are 5 percent (that these figures are realistic is shown in Bosker & Guldemond, 1990). It should be noted that in the actual simulations with the model specification 4 was simplified with the equilibrium point chosen for all pupils at the Low SES specification. Furthermore U_{jk} was assumed to be zero (no mean differences between different school cohorts in the same school at entrance).

So far the model formulation has restricted itself to two levels: the pupil and the classroom. By combining adjacent grades within a school, and by introducing the possibility of a switch of curricular trade the school and educational system level can be introduced. This is done by four definitions:

a) repeating a grade := (STANDARDjk - $ACHIEV_{ijk}$) > 2SD(ACHIEV)$_k$

or in words: a pupil repeats a grade when his achievement level lags more than two standard deviations behind the standard set by the teacher. By repeating a grade the pupil becomes part of a class of a younger generation of pupils, and the pupil will of course enter this class with his last reached performance level. Moreover, by leaving his original class, the teacher can set a higher standard for the rest of the pupils (by definition).

b) a switch from a higher curricular track to a lower one: repeating a grade twice within two years.

Consequently, the pupil switches to the next grade of a lower curricular track.

c) drop out: repeating a grade within two years in the vocational track because the pupil cannot be referred to another curricular track.

d) a switch from a lower curricular track to a higher one:
ACH_{ijkc} = Mean ($ACH_{(j-1)k(c+1)i}$)

When pupil.i in school k of a generation j in curricular track c performs up to the level of a younger generation (j-1) in a higher curricular track, he will switch from one curricular track to the other.

A systems graph of the simulation model for educational effects is depicted in figure 5.1.

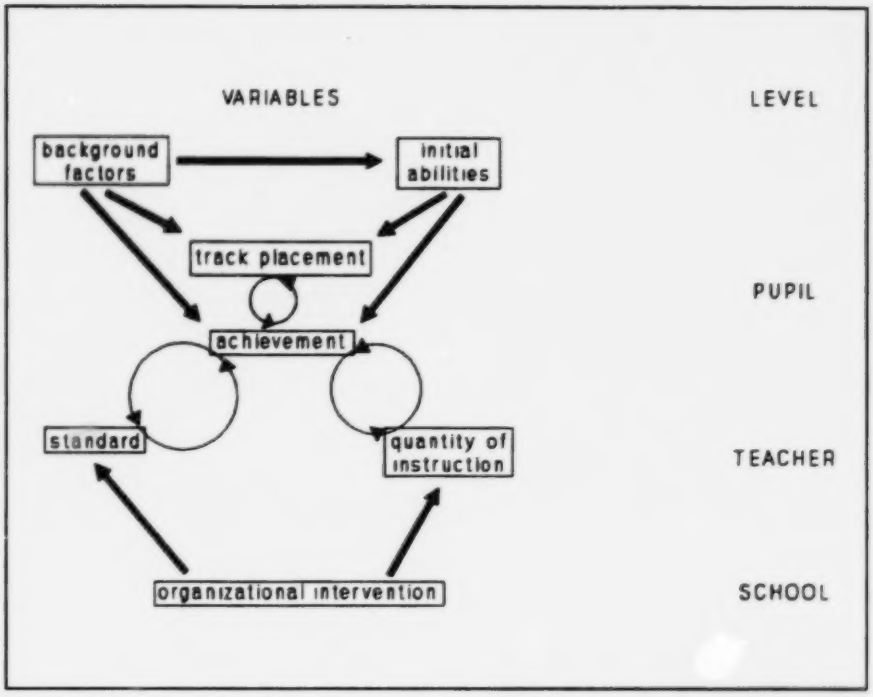

Figure 5.1: A three-level systems dynamics model of pupil achievement

The hierarchical structure has been solved by declaring queues which are linked (the programming is done in PASCAL). Learning progress is modelled as an S-shape function of prior achievement, background characteristics, standards, group heterogeneity and quantity of instruction. Grades are interconnected by those pupils who repeat a grade; tracks are interconnected by those pupils who switch track; pupils are interconnected by the group they are in; classes are interconnected by the school they are in.

The objects in the simulation are 4,137 students from a cohort study conducted by the National Bureau for Statistics. These students are assigned in 4 generations to 85 secondary schools in the simulation. A technical detail is that first of all the simulation starts with treating 4 generations of students to 'fill' the system before the simulation actually starts. The variables defined on the students are the following:

RATING: A score ranging form 1 (apt for individualized junior vocational education) to 13 (apt for pre-university education)

SEX: Coded as 0 for boys and 1 for girls

SES: This is derived form the mean of four indicators: occupational and educational level of both parents. The coding for the educational level is:

1. primay education not completed
2. idem, completed
3. first stage of secondary education (certificate for JVE (LBO) or IGSE (MAVO) or completed grade 3 in HGSE (HAVO) or PUE (VWO))
4. second stage of secondary education (certificate for HGSE or PUE or completed grade 3 in senior vocational education)
5. first stage of higher education (completed firts stage in unversity or completed a vocational college)
6. second stage of higher education (completed university)

The coding for occupational level is:

1.5. worker, employee (low level)
3.0. farmer, small business man
4.5. employee (middle level)
6.0. professions; higher employee

SES is then recoded into three categories.

ACHIEV: Continuous variable with arbritary distribution that develops over time (the initial score is derived from a test taken by the National Institute for Educatinal Measurement) at entry to secondary education. At later stages the outcome of the simulation is used.

IQ: Continuous variable with arbitrary distribution (the so called PSB-test)

TRACK: The assignment of students to one of the four tracks is directly based on information from the cohort-data.

POSITION: This variable describes the position a pupil holds at several timepoints in his schoolcareer. In the analysis we will only work with the the position at entry (START POSITION) and after fours years of schooling: FINAL POSITION. This variable is one of the outcomes of the simulation. The coding is based on the grade the pupil may enter, i.e. if he succesfully has finished JVE-grade-4 the coding is based on being virtually in JVE-grade-5. It is coded as 3: JVE-grade-1; 4: JVE-grade-2 or IGSE-grade-1; 5: JVE-grade-3, IGSE-grade-2 or HGSE-grade-1; 6: JVE-grade-4, IGSE-grade-3, HGSE-grade-2 or PUE-grade-1; 7: IGSE-grade-4, HGSE-grade-3 or PUE-grade-2; 8: HGSE-grade-4 or PUE-grade-3; 9: HGSE-grade-5 or PUE-grade-4; 10: PUE-grade-5.

Chapter 6: Model evaluation

By assessing the validity of the model, the outcomes as produced by the simulation will be compared with results from empirical research. As far correlations are concerned, the outcomes will be compared with data available on an earlier cohort of pupils in secondary education (the so called 'SMVO'-cohort). A drawback of this comparison is, that in this cohort no achievement data other than at entry are available.

Table 6.1: Comparison of the outcomes of the simulation with (between brackets) earlier data (a national cohort of 1976)

	IQ	old Ach.	SES	FINAL
IQ	1.00			
old ACHIEV	.31 (.48)	1.00		
SES	.12 (.16)	.35 (.26)	1.00	
FINAL POSTION	.34 (.38)	.75 (.70)	.38 (.27)	1.00

Comparison of the two series of correlations show some differences, but most of these have to do with that part that enter the simulation model as 'givens'. The output of the model (FINAL POSTION), however, correlates almost as strong with the background variables as the output measure in the empirical data. Only SES has a somewhat stronger relationship with FINAL POSITION, but this is mainly caused by the difference in the other correlations (the partial correlation between SES and FINAL POSITION is .19 for the simulation and .14 for the empirical data, with oldACHIEV partialled out).

To find out how good the model predicts achievement differences the data can be compared with a Dutch national assessment study carried out in 1989 (Kremers, 1990). This study demonstrated that within curricular tracks socio-economic status was not related to achievement in mathematics, biology, dutch language, and english language.

Table 6.2: Achievement broken down by socio-economic status and curricular track

	mean	s.d.	n
JVE (LBO)			
ses low	107.06	8.69	126
ses middle	109.37	8.99	232
ses high	116.13	13.16	19
IGSE (MAVO)			
ses low	119.51	5.07	37
ses middle	121.07	7.62	247
ses high	122.46	7.72	69
HGSE (HAVO)			
ses low	126.19	2.50	6
ses middle	126.92	4.53	129
ses high	129.55	4.86	66
PUE (VWO)			
ses low	138.10	5.50	7
ses middle	133.10	6.48	63
ses high	133.53	7.53	63

The results, based on a 25% random sample of the pupils that had been 'treated' by the simulated education system, indicate that the model indeed is able to reproduce an achievement distribution that varies across the curricular tracks, but hardly across the three socio-economic status groups within curricular tracks. The outstanding scores of low SES pupils in the PUE-track, and vice versa of high SES pupils in the JVE-track, are not significant differing from the scores of the other pupils in these tracks. The differences between the socio-economic groups in the IGSE- and HGSE-track are significant, but nevertheless very small. The model results indicate that the disparity index for the two higher curricular tracks is 8: a pupil from the higher socio-economic status families has a probability of being in one of the two most prestigious tracks that is 8 times as high as that of a pupil with lower socio-economic status.

The results then are satisfying, and for the time being, we consider the model as a valid representation of secondary schooling.

Chapter 7: Evaluating different scenarios

7.1 Defining the scenarios

The common core curriculum as well as the introduction of common achievement norms especially aim at the students in the lower curricukar tracks, i.e. junior vocational (JVE) education and intermediate general education (IGSE). This scenario then might be interpreted as raising standards in these two tracks. In the simulation model this scenario is formalized as follows:

$STANDARD_{jk} = MEAN(ACHIEV)_{jk} + 0.75 * SD(ACHIEV)_{jk}$
(for students in the JVE-track)

$STANDARD_{jk} = MEAN(ACHIEV)_{jk} + 0.60 * SD(ACHIEV)_{jk}$
(for students in the IGSE-track)

Another approach to raise performance levels is to spend extra instruction time on low achieving students, i.e. students that lag far behind the standard set by the teacher. In this scenario instructional time is unevenly distributed over the students of a class, under the condition that the total time spent on instruction by the teacher remains the same. Applying principles of simple linear programming (in other words: applying calcalus) then leads to the following formalization: T_{ij} / classsize is the mean instructional time to be spent on each student. Each student receives at least 10% of the time available for instruction. The total time available for individualized instruction is: $n_j * T_j$, in which n_j represents classsize, with $\Sigma T_{ij} = n_j * T_j$. Each student at least receives $10\%/n_j$ individual instruction. If T_j equals 10% there is no time left for additional instruction. For $T_j > 10\%$ the following rules are applied: students performing at or above the standard do not receive extra instruction; for students performing below the standard the instructional time is given by:

$T_{ij} = \tau_j(STANDARD_{jk} - ACHIEV_{ijk})$

in which the τ's are chosen within the boundary restrictions.

The last scenario to be evaluated aims at improving the achievement levels of low SES students. This is an extention of the second scenario by spending twice as much time on low SES students performing below the standard than on the other students performing below the standard. Then if SES' is a dummy variable (1: low SES; 0: middle class and high SES) we can formalize this by:

$$T_{ij} = \tau_{1j}(STANDARD_{jk} - ACHIEV_{ijk}) + \tau_{2j}(SES'*(STANDARD_{jk} - ACHIEV_{ijk}))$$

under the condition that $\tau_2=2*\tau_1$, with τ_2 being the coefficient for low SES students and τ_1 for the other students. With τ being the coefficient for the average student τ_{1j} can be found by the next equation:

$$\tau = [n_{1j} * \tau_{1j} + (n_{2j} * 2 * \tau_{1j})] / [n_{1j} + n_{2j}]$$

in which n_{2j} is the number of low SES students performing below the standard and n_{1j} are the other students performing below the standard.

7.2 Assessing the effects

In evaluating the effects of the three alternative scenario's against the present situation a hierarchical linear model (Bryk & Raudenbush, 1992) will be used in which SES is the pupil level variable of interest (a factor with three categories, that shows up in the analysis as two dummies), and scenario is the variable of interest at the school level, with four categories (rearranged into three dummies). Moreover, the hypothesised differental effects of the scenarios for pupils with different socio-economic backgrounds imply that the interaction between scenario and SES is also in the model as a crossproduct (6 dummies). Since the simulation was constructed in such a way that for each scenario exactly the same pupils with the same characteristics enter the education system, controlling for IQ, SEX, RATING, TRACK, and initial ACHIEV is already achieved at.

Because of software limitations the statistical analysis is restricted to a 25% random sample of pupils from the simulation.

The distribution of the three dependent variables as a function of the four scenarios is depicted in table 7.1.

Table 7.1: Breakdown of achievement, educational level, and efficiency by scenario

		achievement		educational l.		efficiency	
		mean	s.d.	mean	s.d.	mean	s.d.
scenario	1	119.63	11.72	7.44	1.50	85.47	22.82
	2	120.96	12.08	7.43	1.56	84.19	22.22
	3	113.56	9.60	7.38	1.56	83.83	23.50
	4	110.22	10.29	7.21	1.55	79.73	26.52
Total		116.24	11.83	7.37	1.54	83.38	23.85

The results of the simulation as presented in table 7.1 indicate that the effects to be expected by the three alternative interpretations of the Common Core Curriculum innovation are very modest (and negative) as far educational level and efficiency are concerned. With respect to achievement the results indicate that as with respect to the scenarios where only some pupils (those far below the standard in scenario 3, and only for low SES pupils scoring far below the standard in scenario 4) will benefit from extra instruction, overall achievement levels will decline, and the variance in achievement will decrease. Since the distribution of pupils over educational levels is a relative process (as a consequence of repeating a grade, promotion, drop out, etc. being processes dependent on relative group-dependent rather than absolute standards) this does not affect the general educational level achieved on average, nor the efficiency of the school career in secondary education. To get a first idea of the effects of the scenarios on inequality of educational opportunities, the results are broken down by socio-economic status in table 7.2

Table 7.2: Breakdown of achievement, educational level, and efficiency by scenario and socio-economic status

	achievement		educational l.		efficiency	
	mean	s.d.	mean	s.d.	mean	s.d.
scenario 1						
SES low	111.56	11.13	6.38	1.39	75.11	26.55
SES middle	119.28	11.02	7.43	1.40	86.68	22.09
SES high	127.27	9.38	8.29	1.29	90.14	19.06
scenario 2						
SES low	114.97	10.90	6.55	1.54	76.73	25.80
SES middle	119.28	11.74	7.30	1.48	83.45	22.21
SES high	127.83	10.71	8.36	1.34	91.29	17.21
scenario 3						
SES low	106.69	7.59	6.23	1.38	73.09	26.78
SES middle	112.88	8.92	7.30	1.45	83.65	23.48
SES high	120.64	8.33	8.46	1.30	92.27	16.78
scenario 4						
SES low	106.42	8.51	7.00	1.09	87.88	19.72
SES middle	109.25	10.14	7.01	1.57	76.80	28.28
SES high	115.81	9.79	7.93	1.61	81.57	24.63

Scenario 2 (raising standards in JVE (LBO) and IGSE (MAVO)) nor scenario 3 (extra instruction for those pupils lagging far behind) hardly have any effect on inequality of educational opportunities. Only scenario 4, where the original achievement gap between low and high SES pupils of 16 points has been reduced to 9 points, seems successfull in this respect. As we have seen before, however, this seems to be possible because of a general decline in achievement.

A multilevel statistical test of the effects of the scenarios on student achievement, final educational position, and efficiency are depicted in table 7.3.

Table 7.3: Test of the effects of four different scenarios

		achievement		educational l.		efficiency	
		effect	s.e.	effect	s.e.	effect	s.e.
intercept		119.26		7.44		81.23	
scenario	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.22	1.73	-0.01	0.07	-2.08	2.99
	3	-5.79	1.76	-0.06	0.07	-1.46	3.02
	4	-8.02	1.71	-0.22	0.07	-6.50	2.95

The results of the statistical tests clearly indicate that the fourth scenario has significant negative effects on all three outcome variables. As for the third scenario, this only has significant negative effects on achievement. The explanation of these negative effects is that giving extra instruction to low achieving pupils leads to less gain for the other pupils, and thus to lower standards on average, and thus to less gain, etc. In scenario 4 especially middle and high SES pupils that show a large gap to the standard might be the victims of not getting enough instructional time allocated to them, this resulting in repeating grades, and drop out. Whether or not this indeed is the case can be seen in table 7.4 where the differential effects of the scenarios are put to the test.

Table 7.4: Test of the differential effects of the four different scenarios

		achievement effect	s.e.	educational l. effect	s.e.	efficiency effect	s.e.
intercept		117.54		6.92		74.37	
ses	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.42	0.51	0.31	0.07	8.13	1.83
	3	3.94	0.65	0.35	0.09	9.14	2.31
scen2*ses2		-1.55	0.74	-0.23	0.11	-5.65	2.65
scen2*ses3		-2.15	0.92	-0.07	0.14	-2.58	3.30
scen3*ses2		-0.22	0.74	-0.01	0.11	-2.78	2.65
scen3*ses3		-1.72	0.93	0.13	0.14	1.06	3.32
scen4*ses2		-2.06	0.73	-0.64	0.11	-19.28	2.63
scen4*ses3		-3.87	0.91	-0.52	0.13	-18.18	3.26
scenario	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	2.69	1.79	0.04	0.26	2.04	3.62
	3	-5.27	1.82	-0.11	0.27	0.06	3.64
	4	-5.95	1.77	0.34	0.26	9.32	3.58

With respect to achievement we see that the second scenario (a higher standard in the two lowest curricular tracks) leads to a narrowing of the gap between the socio-economic status groups as existent under the present situation (no change in policy). This might be the case because low SES pupils are overrepresented in the JVE- and IGSE-tracks. On the positive side we find also the result that this scenario leads to less inequality with respect to the education levels attained, although low SES pupils still lag significantly behind high SES pupils.

The third scenario (extra instructional time for those pupils that lag behind) has no significant effects on inequality of educational opportunities, but on the whole it leads to a drastic decline in the performance levels. The fourth scenario (extra instructional time for low SES pupils lagging behind) leads to a significant reduction of inequality, but this is achieved not so much by improving the performance levels of low SES pupils, but by a decline in performance levels of high SES pupils.

Chapter 8: Discussion

In earlier simulation studies of educational systems usually Markov chains are used (i.e. simulation in which history plays no role since all events are described independent of each other) or mono-level system dynamics (i.e. a simulation of how learning takes place ignoring the social context in which it occurs). Educational theories, however, are usually multilevel in their nature, since they describe pupil learning amongst others as a function of characteristics of the group in which this learning takes place. Moreover, teacher behaviour is affected by organizational interventions. A three-level simulation model for educational effectiveness (3LS) was presented. Pupils for the simulation (i.e. objects and their scores on the variables) were sampled from the VOCL database (the CBS-VOCL database contains data on a cohort of approximately 20,000 pupils in 400 secondary schools). The model is based on a theory of De Vos (1989) that focuses on the central role of standard setting by teachers, which can be seen as the lever for raising performance levels. The model provides a good description of how schools work in terms of predictive validity. One part of future research is in finding out the sensitivities of the model, and in validating the model using actual data (achievement and final position) on the cohort pupils that are available now.

Four scenarios were evaluated using the model: the present situation, and three alternative interpretations of the effects of the Common Core Curriculum that schools will implement starting in 1993.
Increasing standards in the lower curricular tracks does not have (significant) effects on the improvement of achievement nor on the final position of the pupils. The scenarios with disproportional assignment of instructional time to students performing below the standard lead to a decrease in achievement (in both scenarios) and to a decrease in the final position in the last scenario (extra time for low SES students). Following the logic of the model the explanation could be that the progress of low achieveing students can not compensate for the relative lack of progress high performing students demonstrate. This then leads to a small decrease in the mean achievement level, such as that students at the bottom of the achievement distribution will not repeat grades (since their distance to the

standard, which is derivated from the mean achievement level, is not large enough). If they do repeat a grade, however, their absolute achievement level is so poor that do not even have a positive impact on the class that they are referred to.

Under all but the last scenario (that had negative overall effects) inequality of educational opportunities is not solved. To some degree raising standards in the lower curricular tracks seems to produce the most promising results, not with respect to the excellence goals but with respect to equity. The gap between low and high SES pupils will become half of what it is in the present situation. An important result for the evaluation of the Common Core Curriculum and the Educational Priority Programme is, that the effects of these innovations will be very small, indicating that the research design chosen and implemented should maximize power: large samples, reliable achievement tests, reliable indices of socio-economic status, etc.

Until now the simulation model is used to do experiments with standards, track placement, and instructional time. Future directions are concerned with the inclusion of new instructional as well as organizational interventions next to the already implemented constraint intervention of maximum class size. These interventions concern constraints on standards for all teachers within the school and constraints on instructional quantity (cf. Barr & Dreeben, 1983). Another modification will concern the inclusion of comprehensive schools in the model, i.e. two curricular tracks that are combined. This will have effect on heterogeneity, and thus on social reference processes. One of the advantages of using simulation models is, that the mathematical formulation forces us to be precise on the relations between the variables. This then may lead to the acknowledgement that there are black holes in our knowledge of education, and thus the formalization helps in guiding future empirical research.

Real intervention studies, using true experimental designs, can hardly be done in educational research because of difficulties in assigning pupils to conditions at random and also because of the difficulty of implementing the complex interventions we are dealing with when we wish to implement organizational and

instructional "treatments". True experimentation then is quite near to impossible in educational settings, if the various layers of school organizations are to be considered simultaneously. Therefore the approach presented in this report may be an alternative to this dilemma. When the theory is formalized, experiments can be carried out by computer simulation. In this way computer simulation can be used as a surrogate for empirical experimental intervention studies.

Experiments with the model show that it is almost impossible to achieve different (possibly conflicting?) policy goals simultaneously. For this reason the system dynamics approach should be combined with operations research, i.c. decision theory: finding decision rules (for instance concerning track placement of pupils) that optimize the three goals (excellence, equity, and efficiency) simultaneously.

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Appendix: source code of 3LS (3-Level Simulation model of Educational Effectiveness)

```
program 3ls( infile , outfile , input , output ,beta );
(* const max = 5 : there are five pupil variables involved
   in the regression equation; max can be raised to ten
   without changing anything in the program. Variables should
   be presented in free-format in the file named infile.
   The first max variables are those that are entered into the
   regression equation. Variable no. 1 is the dependent
   variable. There may be no missing data. Variable no. 2 is
   SES (socio-economic status) scored as low, medium, high. This
   variable in this position is important if one wishes to work
   met more than one standard (see Procedure Process!!). Variables
   read into the program are either integers or reals.
   Procedure "residuals" is written in capitals to indicate that
   it uses external procedures defined in henk.tpu
 *)

 Const  maxx = 10 ;
        max =  5 ;
        maxl = 1000000;
 var    expno : integer;
                              (* expno = experiment number
                                 0 = regular run
                                 1 = higher standards in lbo and mavo
                                 2 = unequal instruction time
                                 3 = as 2 but now with extra instruction
                                     time for low SES pupils
                               *)
type
     realarraynp = array[1..Maxx]of real;
     integerarraynp = array[1..Maxx]of integer ;
     mat = array[1..Maxx,1..Maxx] of real ;
     kind = ^rec;
            rec = record
            ll : array[1..Max]of real ;
            typ : integer ;  (* career in schooltypes *)
            resid : real ;   (* residual score regression equation *)
            Ljr : integer;   (* career in grades *)
            eljr: integer;   (* schooltype and grade at this moment *)
            next : kind ;
            nep  : boolean ;
            doubleer : boolean ;
            merkteken : boolean ;
            leerjaren : integer;
            nummer    : integer;
            aanvang   : integer;
            svtoud    : real ;
            tij       : real
            end;
      queue =^anchor ;
             anchor = record
             school : integer ;
             lichting : integer; (* for times a new generation per school
                                    This is to have bjk = ujk + uk in the
                                    model. With each new generation ujk
                                    is randomly taken, wheras uk is constant
                                    over the four generations
                                       *)
             ujk , uk : real;
             standaard,stdev,gemiddelde : real ;
             eljr : integer ; (* schooltype and grade *)
             length : integer ;
             first , last : kind ;
             tj           : real ; (* instruction time *)
             end;
        rij = array[1..Max] of real ;
```


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```
var eenkind , vorigkind : kind ;
var    hulpqueue, targetqueue, zitqueue ,
    queuelbo,queuemavo,queuehavo,queuevwo : queue ;
      i,j    : integer ;
      infile: text ;
      outfile: text ;
      beta   : text ;
      teller : integer ;
      schnr  : integer ;
      regels  : integer ;
      gemiddelden : array[1..4,1..4] Of real;
      totaal : integer ;
      indxx  : integerarraynp;
      col    : realarraynp;
      dd     : real ;
      trapzdit : integer ;
      zittenblijvers : integer ;
     ran3inext, ran3inextp : integer;
     ran3ma : array [1..55] Of real;
     gasdeviset :  integer;
     gasdevgset : real;
     idum : integer;
     echt : integer;
     xyz :array[0..45]Of integer;

procedure wiedan( q :queue);
var k : kind;
    i : integer;
begin
 for i := 0 to 45 do xyz[i]:=0;
 k := q^.First;
 while ( k <> nil ) do
  begin
   if (k^.Nep = false) then xyz[k^.Eljr]:=xyz[k^.Eljr] + 1;
   k := k^.Next;
  end;
 for i:= 0 to 45 do
  writeln(i:4,' = ', xyz[i]:10);
end;

function tellen( q:queue ):integer;
var k : kind ;
    aantal : integer;
begin
 aantal := 0 ;
 k := q^.First;
 while ( k <> nil ) do
 begin
(*if ( k^.Nep = false ) then *)  aantal := aantal + 1 ;
  k := k^.Next;
 end;
tellen := aantal ;
end;
```

```
function ran3 ( var idum : integer ) : real;

const
   mbig = 4.0E6;
   mseed = 1618033.0;
   Mz = 0.0;
   Fac = 2.5E-7;

var
   i, ii, k : integer;
   mj, mk   : real;

begin
    if idum < 0 then begin
       mj := mseed + idum ;
       if mj >= 0.0 Then
          mj := mj - mbig * trunc(mj/mbig)
       else
          mj := mbig - abs(mj) + mbig * trunc( abs( mj ) / mbig) ;
       ran3ma[55] := mj ;
       mk := 1;
       for i := 1 to 54 do begin
          ii := 21 * i mod 55 ;
          ran3ma[ii] := mk;
          mk := mj - mk ;
          if mk < mz then mk := mk + mbig;
          mj := ran3ma[ii];
      end;
      for k := 1 to 4 do begin
       for i := 1 to 55 do begin
        ran3ma[i] := ran3ma[i] - ran3ma[1 + (i + 30 ) mod 55 ];
        if ran3ma[i] < mz then ran3ma[i] := ran3ma[i] + mbig
       end
      end;
      ran3inext :=0 ;
      ran3inextp := 31 ;
      idum := 1
   end;
   ran3inext := ran3inext + 1 ;
   if ran3inext = 56 then
      ran3inext := 1;
   ran3inextp := ran3inextp + 1 ;
   if ran3inextp = 56 then ran3inextp := 1;
   mj := ran3ma[ran3inext] - ran3ma[ran3inextp];
   if mj < mz then mj := mj + mbig;
   ran3ma[ran3inext] := mj ;
   ran3 := mj * fac
end;

function gasdev ( var idum : integer) :.real;

var
    fac, r, v1, v2 : real ;

begin
   if gasdeviset = 0 then begin
      repeat
         v1 := 2.0 * Ran3( idum ) - 1.0;
         V2 := 2.0 * Ran3( idum ) - 1.0;
         R  := sqr( v1 ) + sqr ( v2 );
      until ( r < 1.0 ) And ( r > 0.0 );
      Fac := sqrt( -2.0 * Ln( r )/r );
      gasdevgset := v1 * fac;
      gasdev := v2 * fac;
      gasdeviset := 1
   end
   else begin
      gasdeviset := 0 ;
      gasdev := gasdevgset;
   end
end;
```

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```
procedure ludcmp(var a: mat; n: integer;
                 var indx: integerarraynp; var d: real);

const
   tiny=1.0E-20;
var
   k,j,imax,i: integer;
   sum,dum,big: real;
   vv : ^realarraynp;

begin
   new(vv);
   for i := 1 to maxx do vv^[i] := 0 ;
   d := 1.0;
   For i := 1 to n do begin
      big := 0.0;
      For j := 1 to n do
       if (abs(a[i,j]) > big) then big := abs(a[i,j]);
      if (big = 0.0) Then begin
         writeln('pause in ludcmp - singular matrix');
      end;
      vv^[i] := 1.0/Big
   end;
   for j := 1 to n do begin
     for i := 1 to j-1 do begin
       sum := a[i,j];
         for k := 1 to i-1 do
             sum := sum-a[i,k]*a[k,j];
         a[i,j] := sum
     end;
     big := 0.0;
     For i := j to n do begin
      sum := a[i,j];
        for k := 1 to j-1 do
        sum := sum-a[i,k]*a[k,j];
     a[i,j] := sum;
     dum := vv^[i]*abs(sum);
     if (dum > big) then begin
         big := dum;
         imax := i
     end
 end;
 if (j <> imax) then begin
     for k := 1 to n do begin
        dum := a[imax,k];
        a[imax,k] := a[j,k];
        a[j,k] := dum
     end;
     d := -d;
     vv^[imax] := vv^[j]
 end;
 indx[j] := imax;
 if (a[j,j] = 0.0) Then a[j,j] := tiny;
 if j <> n then begin
    dum := 1.0/A[j,j];
         for i := j+1 to n do
            a[i,j] := a[i,j]*dum
 end;
 end;
 dispose(vv);
end;
```

```
procedure lubksb(var a: mat; n: integer;
                 var indx: integerarraynp;
                 var b: realarravnp);
var
   j,ip,ii,i: integer;
   sum: real;
begin
   ii := 0;
   for i := 1 to n do begin
      ip := indx[i];
      sum := b[ip];
      b[ip] := b[i];
      if  (ii <> 0) then
         for j := ii to i-1 do
            sum := sum-a[i,j]*b[j]
      else if (sum <> 0.0) Then
         ii := i;
         b[i] := sum
   end;
   for i := n downto 1 do begin
      sum := b[i];
         for j := i+1 to n do
            sum := sum-a[i,j]*b[j];
         b[i] := sum/a[i,i]
   end
end;

procedure inverse(aa : mat ; var yy : mat ; n : integer);

var col : realarraynp;
    i,j : integer;
begin
  ludcmp(aa,n,indxx,dd);
  for j := 1 to n do begin
   for i := 1 to n do col[i] := 0.0;
   Col[j] := 1.0;
   Lubksb(aa,n,indxx,col);
   for i := 1 to n do yy[i,j] := col[i]
   end;
end;

procedure matrixmul(var c:mat;a,b:mat;m,p,n:integer);

var i,j,k:integer;
       s:real    ;
begin
 for i := 1 to m do
  begin
   for j:=1 to n do
      begin
     s:=0;
    for k:=1 to p do s:=s + a[i,k]* b[k,j];
       c[i,j]:=s;
     end;
  end;
end;

procedure cleanmat ( var x : mat );

var i , j : integer ;

begin
 for i := 1 to maxx do
  for j := 1 to maxx do
   x[i,j] := 0 ;
end;

function log10( x :real ) : real ;

const  vari = 0.434294481903252 ;     (* 1/Ln(10) = constant to  *)
                                      (* transform to 10 log     *)
begin
  log10 := vari * ln(x);
end;

function funct( x : real ) : real ;

begin
funct:= 1 / sqrt( 3.1415926535897932385 * 2) * Exp (-1 * (x) * (x) / 2 ) ;
end;
```

```
procedure trapzd( a , b : real ; var s : real ; n : integer );

var
      j : integer ;
      x , tnm , sum , del : real ;

begin
 if n = 1 then begin
    s := 0.5 * ( B - a ) * ( funct(a) + funct(b));
    trapzdit := 1;
 end
 else begin
    tnm := trapzdit ;
    del := ( b - a ) /tnm ;
      x := a + 0.5 * Del  ;
    sum := 0.0 ;
    For j := 1 to trapzdit do begin
        sum := sum + funct(x);
          x := x +  del ;
    end;
    s := 0.5 * ( S + ( b - a ) * sum / tnm);
    trapzdit := 2 * trapzdit
 end
end;

procedure qtrap(  a , b : real; var s : real );

label 99 ;

const
     eps = 1.0E-5 ;
    jmax = 20 ;
var
      j : integer ;
   olds : real ;

begin
   olds := -1.0E30 ;
   for j := 1 to jmax do begin
       trapzd( a, b, s, j );
       if abs( s - olds ) < eps * abs( olds ) then goto 99;
       olds := s
   end;
   writeln('pause in qtrap - too many steps');
   readln;
 99 :
end;

function qlengte(q:queue):integer;
var k : kind ;
    i : integer ;
begin
i := 0 ;
k := q^.First ;
while ( k <> nil ) do
 begin
  i := i + 1 ;
  k := k^.Next ;
 end;
qlengte := i ;
end;
```

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```
procedure varukujk( q:queue);

var multp : real ;
        i : integer ;
        k : kind ;
        stdev : real ;
        mean  : real ;
begin
 mean := 0 ;
 stdev := 0 ;
 k := q^.First ;
 for i := 1 to q^.Length do
  begin
   mean := mean + k^.Ll[1];
   stdev := stdev + k^.Ll[1] * k^.Ll[1];
   k := k^.Next ;
  end;
  mean := mean / (q^.Length );
  stdev := stdev - q^.Length * mean * mean;
  stdev := sqrt( stdev / ( q^.Length - 1 ));
 if ( q^.Lichting = 0 ) then
  begin
   q^.School := q^.School + 1 ;
   q^.Lichting := 4 ;
   q^.Uk := gasdev( idum ) * sqrt(0.1);
   Q^.Tj := trunc( ran3(idum) * 80 ) + 20 ;
  end;
  q^.Ujk := gasdev(idum) * sqrt(0.05);
  Multp := (q^.Uk + q^.Ujk) * stdev ;
  k := q^.First ;
  for i := 1 to q^.Length do
   begin
    k^.Ll[1] := k^.Ll[1] + multp ;
    k := k^.Next ;
   end;
  q^.Lichting := q^.Lichting - 1 ;
end;

procedure nonsingulierxy( var xx :mat ; hulp : rij );
var i , j , k : integer;
begin
 for k := max - 2 downto 1 do
 if ( abs(hulp[k])<0.000000001) Then
  begin
   for i := k to max-1 do
   xx[i]:=xx[i+1];
  end;
end;


procedure nonsingulier( var xx :mat ; hulp : rij );
var i , j , k : integer ;

begin
 for k := max - 2 downto 1 do
  if ( abs(hulp[k])<0.000000001 ) Then
  begin
   for i := 1 to max-1 do
    for j := k to max-1 do
      xx[i,j] := xx[i,j+1];
    for i := 1 to max-1 do
     for j := k to max-1 do
       xx[j,i] := xx[j+1,i];
   end;
end;
```

```
procedure standardbeta( xx , xy : mat ; y2 : real; hulp : rij ;up :integer );
var rxx, rxxi , rxy , stbet  : mat ;
          i,j : integer ;

begin
  for i := 1 to up do
   begin
    if ( abs(xx[i,i])>0.0001 ) Then
    rxy[i,1] := xy[i,1]/ ( sqrt ( xx[i,i] * y2 ) )else rxy[i,1]:=0;
    for j := 1 to up do
    if (( abs(xx[j,j])>0.0001 ) And ( abs(xx[i,i])>0.0001)) Then
     rxx[i,j] := xx[i,j] / (sqrt ( xx[i,i] * xx[j,j] ) )else rxy[i,j]:=0;
   end;
 inverse(rxx, rxxi , up);
 matrixmul(stbet , rxxi , rxy , up ,up , 1 ); write(beta,' ':10);
 j := 1 ;
 for i := 1 to max - 1 do
 if (hulp[i] = 0 ) then write(beta,' ':10) else
 begin
 write(beta,stbet[j,1]:10:5);
 j := j + 1 ;
 end;
 writeln(beta);
end;


procedure tijddistra( q : queue );
var i : integer ;
    k : kind ;
begin
 k := q^.First ;
  for i:= 1 to q^.Length do
  begin
   k^.Tij := q^.Tj;
   k := k^.Next;
  end;
end;

procedure tijddistrb( q : queue );

var nj : integer ;
     i : integer ;
     k : kind    ;
     tauj , sj , devij , sigmatij : real ;
begin
 k := q^.First;
 nj := 0 ;
 sigmatij := 0 ;
 sj       := 0 ;
 tauj     := 0 ;
 devij    := 0 ;

 for i := 1 to q^.Length do
  begin
  if ( k^.Ll[1] < q^.Standaard ) then
   begin
    nj := nj + 1;
    devij := devij + q^.Standaard - k^.Ll[1]
   end;
  k := k^.Next;
  end;
  sigmatij := q^.Length * q^.Tj - q^.Length * 10 ;
  sj := sigmatij / nj ;
  devij := devij / nj ;
  tauj  := sj / devij ;

  k := q^.First;
  for i := 1 to q^.Length do
   begin
      if ( k^.Ll[1] < q^.Standaard ) then
       k^.Tij := tauj * ( q^.Standaard - k^.Ll[1] ) + 10
      else
       k^.Tij := 10;
     k := k^.Next;
   end;
end;
```


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```
procedure tijddistrc( q : queue );

var nj : integer ;
     i : integer ;
     k : kind    ;
     laag_ses , hoog_ses : integer ;
     tauj , sj , devij , sigmatij , taulj , tau2j  : real ;
begin
 k := q^.First;
 nj := 0 ;
 sigmatij := 0 ;
 sj       := 0 ;
 tauj     := 0 ;
 devij    := 0 ;
 laag_ses := 0 ;
 hoog_ses := 0 ;
 for i := 1 to q^.Length do
  begin
  if ( k^.L1[1] < q^.Standaard ) then
   begin
    if ( k^.L1[2] = 1 ) then laag_ses := laag_ses + 1 else
                             hoog_ses := hoog_ses + 1;
    nj := nj + 1;
    devij := devij + q^.Standaard - k^.L1[1]
   end;
  k := k^.Next;
  end;
  sigmatij := q^.Length * q^.Tj - q^.Length * 10 ;
  sj := sigmatij / nj ;
  devij := devij / nj ;
  tauj  := sj / devij ;
  taulj := tauj * nj / ( 2 * laag_ses + hoog_ses );
  tau2j := taulj * 2;
  k := q^.First;
  for i := 1 to q^.Length do
   begin
     if (( k^.L1[1] < q^.Standaard) and ( k^.L1[2] = 1 ) ) then
      k^.Tij := tau2j * ( q^.Standaard - k^.L1[1] ) + 10
     else
     if (( k^.L1[1] < q^.Standaard) and ( k^.L1[2] = 0 ) ) then
     k^.Tij := taulj * ( q^.Standaard - k^.L1[1] ) + 10
     else
      k^.Tij := 10;
    k := k^.Next;
   end;
end;
```

```
procedure residuals( qq : queue );
var xy , xx , h , r , ht , ma: mat; (* henk.Tpu array[1..5,1..5]Of real *)
     regel , hulp : rij ;
     i , j , k : integer ;
     inter : real ;
     typ,n : integer;
         q : kind ;
    y2 , yp : real ;
    missing : integer;
begin
 n:= qq^.Length ;
 q := qq^.First ;
 cleanmat(xy);
 cleanmat(xx);
 cleanmat(r);
 cleanmat(h);
 (* calculation of residuals using regression analysis
    first we calculate a sscp-matrix:  x'x = x'x - xm'xm,
    in which xm = matrix with mean scores.
    For technical reasons this is reformulated as x'x - n * xi * xj.
    (Xi and xj are the mean scores for var i and j; n = #
     of cases.
    We do not need the transpose of xm and so we avoid large matrices.
    As a reference for this procedure see: Tatsuoka (1971) p. 30 .
    First of all in calculating the sscp-matrix both y- and  x- variables
    are involved. In a next step the matrices spp en spc are constructed.
    Once the inverse of spp is found, the beta-weights and intercept can be
    readily deduced.
 *)
 For i := 1 to max do regel[i]:=0;
 (* means and sum of squares and sum of crossproducts *)
 for i := 1 to n do
  begin
   for j := 1 to max do
     regel[j] := regel[j] + q^.L1[j] ;
    for j := 1 to max do
     for k := 1 to max do
     xx[j,k] := xx[j,k] + q^.L1[j] * q^.L1[k];
   q := q^.Next;
  end;
  (* means *)
  for i := 1 to max do
  regel[i]:= regel[i]/n ;
 (* sum of squares etc. In the form of deviations *)
 for j:= 1 to max do
  for k:= 1 to max do
  xx[j,k] := xx[j,k] - n * regel[k] * regel[j];
   y2 := xx[1,1];
 (* matrices spp and spc *)
 for i := 2 to max do
 xy[i-1,1] := xx[i,1];
 for i := 1 to max-1 do
  for j := 1 to max-1 do
  begin
   h[i,j] := xx[i+1,j+1];
   ma[i,j] := h[i,j];
  end;
   qq^.Stdev := sqrt( xx[1,1] / ( n - 1 ) );
  cleanmat(xx);
 (* avoid singular matrices because we want to calculate the inverse *)
 for i := 1 to max do  hulp[i]:=0;
 missing := 0 ;
   for i := 1 to max-1 do
     for j := 1 to max-1  do
      hulp[j] := hulp[j] + h[i,j];
   for i := 1 to max-1 do
      if (abs(hulp[i]) <= 0.000000001 ) Then missing := missing + 1 ;
      if (missing > 0 ) then
      begin
       nonsingulier( ma  , hulp );
       nonsingulier( h   , hulp );
       nonsingulierxy( xy  , hulp);
      end;
```

6i

```
  (*inverse of spp *)
  inverse(h,xx,max-1-missing);
  cleanmat(h);
  (* inverse spp * spc = beta *)
  matrixmul(h,xx,xy,max-1-missing,max-1-missing,1);
  (* estimate the intercept *)
  inter := regel[1] ;
  j := 1 ;
  for i := 1 to max-1 do if ( hulp[i] <> 0 ) then
  begin
  inter := inter - h[j,1] * regel[i+1];
  j := j + 1 ;
  end;
  write(beta,inter:10:5);
  j := 1 ;
  for i := 1 to max - 1 do
  if ( hulp[i] <> 0 ) then
  begin
  write(beta,h[j,1]:10:5);
  j := j + 1 ;
  end
  else write(beta,' ':10);
   j := 1 ;
  cleanmat(ht);
  for i:= 1 to max-1- missing do
   ht[1,i] := h[i,1];
   matrixmul(r,ht,xy,1,max-1-missing,1);
  writeln(beta,'     ',1/y2 * r[1,1] :4:2);
   standardbeta(ma,xy,y2,hulp,max-1-missing);
   q := qq^.First ;
  (* estimation of residuals *)
  for j := 1 to n do
  begin
   yp := inter ;
   for i := 2 to max do
    yp := yp + q^.Ll[i] * h[i-1,1];
    q^.Resid := q^.Ll[1] - yp;
    q := q^.Next ;
   end;
  qq^.Standaard := regel[1] + 0.5 * Qq^.Stdev ;
  qq^.Gemiddelde := regel[1];

 typ := qq^.Eljr div 10;
 if ( (expno = 1 ) and (( typ = 1 ) or ( typ = 2 ))) then
  begin
   case typ of
   1 : qq^.Standaard := qq^.Gemiddelde + 0.75 * Qq^.Stdev;
   2 : qq^.Standaard := qq^.Gemiddelde + 0.60 * Qq^.Stdev;
   end;
  end;

  gemiddelden[qq^.Eljr div 10,qq^.Eljr mod 10 ] :=
  gemiddelden[qq^.Eljr div 10,qq^.Eljr mod 10 ] + 1;
end;


function initkind : kind ;

var i : integer ;
    k : kind ;

begin
 new( k ) ;
  for i := 1 to max do k^.Ll[i] := 0 ;
  k^.Eljr := 0 ;
  k^.Typ := 0 ;
  k^.Ljr  := 1 ;
  k^.Resid := 0 ;
  k^.Next := nil ;
  k^.Doubleer := false;
  k^.Merkteken := false;
  k^.Leerjaren := 1 ;
  k^.Nummer := teller;
  teller := teller + 1;
  k^.Tij := 0;
  initkind := k ;
end;
```

```
procedure inqueue( hhqueue : queue ; eenkind : kind );
begin
  eenkind^.Next := nil ;
  if (hhqueue^.First = nil ) then
  begin
   hhqueue^.First := eenkind ;
   hhqueue^.Last  := eenkind ;
  end
  else
  begin
   hhqueue^.Last^.Next := eenkind;
   hhqueue^.Last  := eenkind ;
  end;
  hhqueue^.Length := hhqueue^.Length + 1 ;
end;


procedure vulklas ( tqueue : queue ; hqueue : queue ; var i : integer;
                    typjaar : integer );

var ditkind , vorigkind  : kind ;
        er ,  gevonden   : integer;
                    ch   : char;
begin
 gevonden := i ;
 ditkind := hqueue^.First ;
 vorigkind := hqueue^.First ;
 while ( ( ditkind <> nil ) and ( i > 0 )) do
 begin
  er := ditkind^.Eljr ;
  while ( ( ditkind <> nil ) and ( er <> typjaar )) do
   begin
    vorigkind := ditkind ;
    ditkind := ditkind^.Next ;
    if ( ditkind <> nil ) then er := ditkind^.Eljr ;
   end;
  if ( ditkind <> nil ) then
  begin
   i := i - 1 ; hqueue^.Length := hqueue^.Length - 1 ;
   if ( ditkind = hqueue^.First ) then
    begin
     hqueue^.First := ditkind^.Next;
     vorigkind := hqueue^.First ;
     inqueue(tqueue,ditkind );
     ditkind := hqueue^.First;
    end
    else if (ditkind = hqueue^.Last ) then
    begin
     vorigkind^.Next := nil ;
     hqueue^.Last := vorigkind;
     inqueue(tqueue,ditkind);
     ditkind := nil ;
    end
    else
    begin
     vorigkind^.Next := ditkind^.Next ;
     inqueue ( tqueue , ditkind );
     ditkind := vorigkind^.Next;
    end;
   end;
  end;
end;

function leeskind( k : kind ) : kind ;
var i : integer ;

begin
 for i := 1 to max do read(infile,k^.L1[i]);
 regels :=  regels + 1 ;
 readln(infile,k^.Typ);
 k^.aanvang := k^.typ;
 K^.Eljr := k^.Typ * 10 + 1 ;
 k^.Nep := false ;
 k^.Svtoud := k^.L1[1];
 leeskind := k ;
end;
```

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```
procedure loopbaan (  p :kind ; i : integer );

var h1,h2 : integer ;

begin
   h2 := p^.Eljr mod 10 ;
   h1 := p^.Eljr div 10 ;
if ( p^.Typ  <  max1 ) then
begin
case i of
 0 :  begin
       p^.Merkteken := true ;
       p^.Leerjaren := p^.Leerjaren  + 1 ;
        if ( p^.Doubleer = true )  then
         begin
          p^.Doubleer := false ;
          if ( h1 > 1 ) then
            p^.Eljr := (h1 - 1 ) * 10  + h2 ;
          p^.Typ := p^.Typ * 10 + h1 - 1 ;
          p^.Ljr := p^.Ljr * 10 + h2 ;
         end
         else
         begin
          p^.Doubleer := true ;
          p^.Typ := p^.Typ * 10 + h1 ;
          p^.Ljr := p^.Ljr * 10 + h2 ;
         end
       end;
 1 :    begin
         p^.Typ := p^.Typ * 10 + h1;
         p^.Ljr := p^.Ljr * 10 + h2 + 1 ;
         p^.Leerjaren := p^.Leerjaren * 10 + 1 ;
         p^.Eljr := p^.Eljr + 1 ;
        end;
 2 :    if   ( h1 < 4 ) then
         begin
          p^.Typ := p^.Typ * 10 + h1 + 1;
          p^.Ljr := p^.Ljr * 10 + h2;
          p^.Eljr := ( h1 + 1 ) * 10 + h2;
          p^.Leerjaren := p^.Leerjaren * 10 + 1 ;
         end
         else
         begin
          p^.Typ := p^.Typ * 10 + h1;
          p^.Ljr := p^.Ljr * 10 + h2 + 1;
          p^.Eljr := p^.Eljr + 1;
          p^.Leerjaren := p^.Leerjaren * 10 + 1 ;
         end;
     end;
  end else p^.Eljr := p^.Eljr + 1 ;
end;

procedure freequeue ( var q : queue );

var k1 , k2 : kind ;

begin
 k1 := q^.First;
 k2 := k1^.Next;
 while ( k2 <> nil ) do
  begin
   dispose(k1);
   k1 := k2 ;
   k2 := k2^.Next;
  end;
 dispose(k1);
 with q^ do
 begin
  length := 0;
  stdev  := 0;
  gemiddelde := 0;
  standaard  := 0;
  eljr       := 0;
  first      := nil ;
  last       := nil ;
 end;
end;
```

```
procedure schoolwissel( var k, hulp : kind ; dezerij ,wachtrij : queue );
begin
dezerij^.Length := dezerij^.Length - 1 ;
if ( k = dezerij^.First ) then
 begin
  dezerij^.First := k^.Next;
  inqueue( wachtrij , k );
  k := dezerij^.First;
  hulp := dezerij^.First;
 end
else   if ( k = dezerij^.Last ) then
 begin
  hulp^.Next := nil ;
  dezerij^.Last := hulp;
  inqueue(wachtrij,k);
  k := nil ;
 end
 else
 begin
  hulp^.Next := k^.Next ;
  inqueue(wachtrij , k );
  k := hulp^.Next;
 end;
end;
```

```
procedure process( q : queue ; serieus : integer );

(* this procedure uses for the pc-version an external in henk.tpu
   defined procedure called qtrap. For more detailed information see:
   numerical recipes in pascal: integration of functions, p. 126.
   This routine accomplishes that the learning gain is inversely
   proportional to the distance to the standard. Qtrap produces a
   value between 0 and 1. This value is multiplied with a random
   digit chosen between 0 and 2 times the standard deviation of
   achievement in a class. The result is added to the achievement.
   This calculation is only used for pupils with negative residuals,
   being underachievers. The other pupils (overachievers) have a chance
   on gain in achievement of 0.5 * Random digit chosen between 0 and 1
   standarddeviation of achievement and a chance of 0.5 on making no
   progress
*)
var hq : queue ;
     k , hulp: kind ;
     i : integer ;
     fractie , leerwinst : real ;
     standaard : array[1..3] Of real ;
     optimum  :  realarraynp;
begin
 for i := 1 to 3 do
  standaard[i] := q^.Standaard ;
  (* initersection as the equilibrium between marginal costs and benefits
   specified for three SES groups seperately ; THIS IS AN OPTION *)
  optimum[1] := 0 ;
  optimum[2] := 0 ; (*(q^.Standaard - q^.Gemiddelde)/2;*)
  optimum[3] := 0 ; (*(q^.Standaard - q^.Gemiddelde);*)
  (* standard can be differentiated between three groups of pupils;
     in this setup we only use one standard
     n.b. three standards for low [1], medium [2] and high [3] SES pupils *)
(*  if  ( serieus = 0 )  then hq := hulpqueue
       else hq := zitqueue ;   *)
  case expno of
  0 : tijddistra(q);
  1 : tijddistra(q);
  2 : tijddistrb(q);
  3 : tijddistrc(q);
  end;
 k := q^.First ;
  for i:= 1 to q^.Length do
  begin
  (* was if ( k^.Resid < 0 ) then *)
  if (k^.Resid < optimum[trunc(k^.Ll[2])] ) then
   begin
    qtrap ( ( k^.Ll[1] - q^.Gemiddelde )/q^.Stdev ,
   (optimum[trunc(k^.Ll[2])])/q^.Stdev ,fractie ) ;
    fractie := ( 1 - fractie );
    k^.Ll[1] := k^.Ll[1] + fractie * log10(k^.Tij)/log10(55)
(*  * ran3(idum) *) * ( trunc (  q^.Stdev ) ) ;
   end
  else
    k^.Ll[1] := k^.Ll[1] + log10(k^.Tij)/log10(55) *
      ran3(idum) * ( trunc ( q^.Stdev ) ) - 0.5 * Q^.Stdev;
    k := k^.Next;
  end;
   residuals(q);
   hulp := q^.First ;
   k    := q^.First ;
  for i:= 1 to q^.Length do
   begin
    if ( k^.Nep = false) then hq := zitqueue
     else hq := hulpqueue ;
    if ( (k^.Ll[1]) < (standaard[1] - 0.99 * Q^.Stdev ) ) then
     begin
      loopbaan( k , 0 );
      zittenblijvers := zittenblijvers + 1 ;
      schoolwissel( k , hulp , q , hq );
     end
     else
      if ( (q^.Eljr div 10 < 4 ) and (k^.Ll[1] >
            (q^.Gemiddelde + 2 * q^.Stdev)) ) then
 (*   ( gemiddelden[(q^.Eljr div 10) + 1 ,q^.Eljr mod 10 ] ) ) ) then  *)
```


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```
      begin
        loopbaan( k , 2 );
        schoolwissel( k , hulp , q , hq );
       end
       else
       begin
        loopbaan( k , 1 );
        hulp := k ;
        k := k^.Next ;
       end;
      end;

      q^.Eljr := q^.Eljr + 1 ;
        if ( q^.Length < 35) then
        begin
         i :=round(ran3(idum) * 10 );
         if ( serieus = 0 ) then
          vulklas( q , hq , i , q^.Eljr )
        else
         begin
          vulklas( q , zitqueue , i , q^.Eljr );
          if ( i > 0 ) then
           vulklas( q , hulpqueue , i , q^.Eljr )
         end;
      end;
end;

procedure schrijfweg( q : queue );

var k : kind ;
    i : integer ;
begin
  k := q^.First ;
  while (  k <> nil ) do
  begin
   if ( k^.Nep = false ) then
   begin
    while ( k^.Typ  > max1 ) do
     begin
      k^.Typ := k^.Typ div 10 ;
      k^.Ljr := k^.Ljr div 10 ;
     end;
    write(outfile,q^.school:4,q^.lichting:1,K^.Nummer:5);
    write(outfile,k^.aanvang:4,K^.Eljr:4 );
    for i := 1 to max do
     write(outfile,k^.Ll[i]:10:3);
     write(outfile,k^.Typ:10);
     writeln(outfile,k^.Svtoud:10:3,k^.Ljr:10,k^.Leerjaren:10);
    end;
    k := k^.Next ;
   end;
end;
```

```
procedure verwerkfile ( serieus : integer );
var   k : kind ;
      i , h , r : integer ;
      somequeue : queue ;
      kladvar   : integer;
begin
  r := 25 + round(ran3(idum) * 5);  (* class size between 25 and 30 pupils *)
  while not eof(infile) do
 begin
  k := initkind ;
  k := leeskind(k);
  if ( (  serieus = 0 )  or (  serieus = 2 ) )  then
  k^.Nep := true else begin echt:=echt+1;    k^.Nep := false ; end;

  case k^.Typ of
  1 : inqueue( queuelbo ,k);
  2 : inqueue(queuemavo ,k);
  3 : inqueue(queuehavo ,k);
  4 : inqueue(queuevwo  ,k);
  end;
  somequeue := nil ;
  if (queuelbo^.Length >= r ) then begin somequeue := queuelbo;
  somequeue^.Eljr := 11  end
   else
   if (queuemavo^.Length >= r ) then begin somequeue := queuemavo;
    somequeue^.Eljr := 21  end
    else
     if (queuehavo^.Length >= r ) then begin somequeue := queuehavo ;
      somequeue^.Eljr :=31 end
     else
      if ( queuevwo^.Length >= r ) then begin somequeue := queuevwo;
      somequeue^.Eljr := 41 end;
  if ( somequeue <> nil ) then
   begin
(* a small adjustement to enter pupils repeating the first grade *)
        i := 10 ; (* round(ran3(idum) * 10 );  *)
        if ( serieus = 0 ) then
         vulklas( somequeue ,hulpqueue, i , somequeue^.Eljr )
       else
        begin
         vulklas( somequeue , zitqueue , i , somequeue^.Eljr );
         if ( i > 0 ) then
          vulklas( somequeue , hulpqueue , i , somequeue^.Eljr )
        end;
(* end of adjustment; for the pc-version this part has to be MODIFIED *)
    varukujk( somequeue  );
    residuals( somequeue );

    process(somequeue  , serieus );
    for h :=1 to 3 do
    process( somequeue  , serieus );
   (* if ( serieus = 1 ) then *)
    schrijfweg( somequeue );
    freequeue( somequeue );
    r := 25 + round(  ran3(idum) * 5);
   end;
 end;
end;

procedure initqueue( q : queue );

begin

 with q^ do
  begin
   school := 0 ;
   lichting := 4 ;
   uk := gasdev(idum) * sqrt(0.1);

   Length := 0 ;
   stdev  := 0 ;
   standaard := 0 ;
   first := nil ;
   last  := nil ;
   eljr  := 0 ;
   tj    := trunc(ran3(idum) * 80 ) + 20 ;
  end;
end;
```

```
begin (* main program *)
 writeln('   which experiment do you want to conduct? (0..3)?');
 writeln('   0 = the present situation (unchanged policy)');
 writeln('   1 = higher standards in lbo and mavo ');
 writeln('   2 = unequal instruction time ');
 writeln('   3 = as with 2 but with extra time for low SES pupils ');
 readln(expno);
  for i := 1 to 4 do
   for j := 1 to 4 do gemiddelden[i,j] := 0;
  gasdeviset := 0 ;
  regels := 0 ;
  teller := 1 ;
  totaal := 0 ;
  schnr  := 0 ;
  echt := 0 ;
  zittenblijvers := 0 ;
(* the variable idum takes care of the random sampling of pupils from the file
   infile.dat; by changing idum we will sample other pupils *)
  idum :=  15000;
  idum := -1 * idum ;
  Reset(infile);
  rewrite(outfile);
  rewrite(beta);
  new(hulpqueue) ;
  initqueue(hulpqueue);
  new(zitqueue) ;
  initqueue(zitqueue);
  new(queuelbo) ;
  initqueue(queuelbo);
  queuelbo^.School := 1000 ;
  new(queuemavo) ;
  initqueue(queuemavo);
  queuemavo^.School := 2000 ;
  new(queuehavo) ;
  initqueue(queuehavo);
  queuehavo^.School := 3000 ;
  new(queuevwo) ;
  initqueue(queuevwo);
  queuevwo^.School := 4000 ;
  verwerkfile( 0 );
  reset(infile);
  verwerkfile( 1 );
  reset(infile);
  verwerkfile( 2 );
  writeln;writeln;
  for i := 1 to 4 do
   begin
    for j := 1 to 4 do
    write(gemiddelden[i,j]:10:4);
    writeln;
   end;
  writeln(' lengte wachtrij       : ',qlengte(hulpqueue):10);
  writeln(' zittenblijvers        : ',zittenblijvers:10);
  writeln(' het totale legioen    : ',teller : 10 );
  writeln(' zitqueue              : ',qlengte(zitqueue):10);
  writeln;writeln('=======================================');
  writeln;writeln('echte cases    : ',echt:10);
  writeln('hulpqueue              : ',tellen(hulpqueue):10);
  writeln('zitqueue               : ',tellen(zitqueue):10);
  writeln('queuelbo               : ',tellen(queuelbo):10);
  writeln('queuelbo^.Length       : ',queuelbo^.Length:10);
  writeln('queuemavo              : ',tellen(queuemavo):10);
  writeln('queuemavo^.Length      : ',queuemavo^.Length:10);
  writeln('queuehavo              : ',tellen(queuehavo):10);
  writeln('queuehavo^.Length      : ',queuehavo^.Length:10);
  writeln('queuevwo               : ',tellen(queuevwo):10);
  writeln('queuevwo^.Length       : ',queuevwo^.Length:10);
  wiedan(zitqueue);
(* the last line is an option to make sure that we write remaining pupils
   schrijfweg(zitqueue);
   used to warm up the system; we are not interested, however, in these
   pupils *)
End.
```


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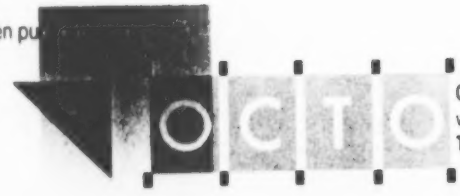

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